DRAFT

Total Maximum Daily Loads
For Algae, Turbidity and Chlordane
Ottumwa Lagoon
Wapello County, Iowa

2005

Iowa Department of Natural Resources
Watershed Improvement Section

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1. Executive Summary

Table 1. Ottumwa Lagoon Summary

Waterbody Name:	Ottumwa Lagoon (a.k.a. Greater Ottumwa Central Park Ponds)
County:	Wapello
Use Designation Class:	A1 (primary contact recreation) B(LW) (aquatic life)
Major River Basin:	Des Moines River Basin
Pollutants:	Algae, Turbidity and Chlordane
Pollutant Sources:	Nonpoint, point (regulated storm water and combined sewer overflows), internal recycle, atmospheric (background)
Impaired Use(s):	A1 (primary contact recreation) B(LW) (aquatic life)
2002 303d Priority:	Medium (algae, turbidity), High (chlordane)
Watershed Area:	2,300 acres
Lake Area:	70 acres
Lake Volume:	467 acre-ft
Detention Time:	0.24 years
TSI (nutrient) Targets:	Total Phosphorus less than 70; Chlorophyll a less than 65; Secchi Depth less than 65
Total Phosphorus Load Capacity (TMDL):	See Table 2
Existing Total Phosphorus Load:	3,410 pounds per year
Total Phosphorus Load Reduction to Achieve TMDL:	See Table 2
Total Phosphorus Margin of Safety:	Implicit
Total Phosphorus Wasteload Allocation:	See Table 2
Total Phosphorus Load Allocation:	See Table 2
Chlordane Load Capacity (TMDL):	0
Existing Chlordane Load:	0
Chlordane Load Reduction to Achieve TMDL:	0
Chlordane Margin of Safety:	Implicit
Chlordane Wasteload Allocation:	0
Chlordane Load Allocation:	0

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop Total Maximum Daily Loads (TMDLs) for waters that have been identified on the state's 303(d) list as impaired by pollutants. Ottumwa Lagoon has been identified as impaired by algae, turbidity and chlordane. As later explained in Section 3 of this document, the algae and turbidity impairments are symptomatic of excessive phosphorus and suspended solids loading to the lake. Phosphorus, which is related through the Trophic State Index (TSI) to chlorophyll and Secchi depth (a measurement of water clarity), is targeted to address the algae and turbidity impairments. Suspended solids, which are composed of both organic and inorganic particulate matter, are the primary transport mechanism for phosphorus. Load and wasteload allocations for suspended solids are not included in this TMDL. However, reductions in phosphorus loading should produce corresponding reductions in the suspended solids load. The purpose of the TMDLs included herein is to determine the maximum allowable phosphorus and chlordane loads that the lake can receive and still meet water quality standards.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. The TMDL will have two phases. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Phase 1 will consist of setting specific and quantifiable targets for total phosphorus, algal biomass, Secchi depth and chlordane. The targets for total phosphorus, algal biomass, and Secchi depth will be related to the lake's trophic state through the TSI.

A monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

Monitoring is essential to all TMDLs in order to:

- Assess the future beneficial use status;
- Determine if the water quality is improving, degrading or remaining status quo;
- Evaluate the effectiveness of implemented best management practices.

The additional data collected will be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairments. The data and information can also be used to determine if the TMDLs have accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in-lake response to pollutant loads, etc.) and if revisions are appropriate.

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Ottumwa Lagoon, S25, T72N, R14W, within the corporate limits of Ottumwa, Iowa.

2. **Identification of the pollutant and applicable water quality standards:** The pollutants causing the water quality impairments are algae, turbidity and chlordane. The algae and turbidity impairments are associated with excessive phosphorus loading. Designated uses for Ottumwa Lagoon are Primary Contact Recreation (Class A1) and Aquatic Life Support (Class B(LW)). Excess phosphorus loading and the historical use of chlordane within the watershed

have impaired aesthetic and aquatic life water quality narrative criteria (567 IAC 61.3(2)) and human health criteria for fish consumption (567 IAC 61.2(1)).

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The Phase 1 TSI targets are values of less than 70 for total phosphorus, and less than 65 for both chlorophyll a and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 96 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters. The desired endpoint for chlordane is to achieve two consecutive samples with all fish tissue chlordane levels below the Food and Drug Administration (FDA) action level of 0.3 milligrams per kilogram (mg/kg or parts per million).

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The existing mean values for Secchi depth, chlorophyll-a and total phosphorus based on 2000 - 2004 sampling are 0.4 meters, 79 ug/L, and 295 ug/L, respectively. A minimum in-lake increase in Secchi transparency of 75% and minimum in-lake reductions of 58% for chlorophyll a and 67% for total phosphorus are required to achieve the TSI targets. The estimated existing annual total phosphorus load to Ottumwa Lagoon is 3,410 pounds per year. The total phosphorus loading capacity for the lake based on lake response modeling is a function of the relative contribution of internal and external loads as shown in Table 2 and as described by the mathematical relationship given in Appendix E.

   The use of chlordane was banned in 1988, so no additional chlordane is being introduced into the environment. The existing watershed load is estimated as zero and the allowable load is also set at zero.

5. **Identification of pollution source categories:** Point (regulated storm water and Combined Sewer Overflows (CSOs)), nonpoint, atmospheric deposition (background), and internal recycling of phosphorus from the lake bottom sediments are identified as the sources of phosphorus loading to Ottumwa Lagoon. Historical chlordane loading to the lake most likely originated from urban and agricultural runoff from areas where chlordane was used as an insecticide, as well as through basement sump/foundation drain connections that may be connected to the combined sewer system and associated CSOs that discharge to the lake.

6. **Wasteload allocations for pollutants from point sources:** Both municipal wastewater and regulated storm water discharges are sources of phosphorus loading to the lake. The City of Ottumwa currently maintains a sewer collection system within the watershed which collects and transports combined storm water and raw municipal wastewater. During periods of wet weather, storm water flows increase until the capacity of the sewer system is exceeded and excess

commingled storm water and raw wastewater are discharged to the lake and the Des Moines River at various overflow points designated as Combined Sewer Overflows (CSOs). These discharges are authorized under the City's wastewater NPDES permit (IA NPDES #9083001), which includes associated special conditions requiring minimum control measures to reduce the impacts of the CSOs. Two CSOs discharge to Ottumwa Lagoon. The City has established a long-term CSO Plan of Action that will separate storm and sanitary sewers throughout the southern portion of the City. One of the CSOs that discharges to the lake (CSO # 010 a.k.a. Moore Street Pump Station CSO) is scheduled to be separated by October 2007. The second CSO that discharges to the lake (CSO # 009 a.k.a. Richmond Avenue Pump Station CSO) is scheduled to be separated by October 2013. Once separation of these sewer systems is complete the contribution of domestic sewage to the lake during wet weather events will be eliminated.

In addition, the City of Ottumwa is authorized to discharge from a Municipal Separate Storm Sewer System (MS4) under Iowa NPDES Permit #9083003 for municipal storm water discharges that are not associated with CSOs. Since the CSOs that discharge to the lake are currently scheduled for separation, the wasteload allocation for total phosphorus in this TMDL will be attributed entirely to the MS4 permit. The total phosphorus wasteload allocation is shown in Table 2.

The use of chlordane was banned in 1988. There will be no discharge of chlordane from point sources into Ottumwa Lagoon. Therefore, the wasteload allocation for chlordane is zero.

7. **Load allocations for pollutants from nonpoint sources:** The total phosphorus load allocation for nonpoint sources is shown in Table 2. This includes 30 pounds per year attributable to atmospheric deposition directly on the lake surface.

   The use of chlordane was banned in 1988. There will be no further application of chlordane in the watershed, where it might be discharged through runoff conditions and enter the lake. Therefore, the load allocation for chlordane is zero.

8. **A margin of safety:** An implicit margin of safety has been included by calculating total phosphorus loads using an in-lake concentration 10% below the desired endpoint to ensure that the required load reduction will result in attainment of water quality targets.

   For chlordane, an implicit margin of safety is included in that two consecutive biennial samples with all fish tissue chlordane levels below the FDA action level will be required to meet the TMDL endpoint.

9. **Consideration of seasonal variation:** The algae and turbidity TMDL was developed based on the annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September). Seasonal variation for chlordane is not a consideration.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** Approximately 78% of the lake drainage area is currently within the corporate limits of the City of Ottumwa. To account for potential future development of the watershed, the total phosphorus load and wasteload allocations have been determined as a function of the drainage area included in the MS4 permit, which covers areas within the City's corporate limits.

11. **Implementation plan:** Although not required by the current regulations, an implementation plan is outlined in the report.

Table 2. Ottumwa Lagoon Target Total Phosphorus Loads

Total Phosphorus TMDL (lbs/year)		Total Phosphorus Allocations for MS4 Area = 1,730 Acres (lbs/year)		Required Load Reduction (lbs/year)
Internal	External	WLA	LA	
0	1,070	810	260	2,340
10	1,040	790	260	2,360
20	1,020	770	270	2,370
30	1,000	750	280	2,380
40	980	740	280	2,390
50	950	720	280	2,410
60	930	700	290	2,420
70	910	680	300	2,430
80	880	660	300	2,450
90	860	650	300	2,460
100	840	630	310	2,470
110	820	610	320	2,480
120	790	590	320	2,500
130	770	580	320	2,510
140	750	560	330	2,520
150	720	540	330	2,540
160	700	520	340	2,550
170	680	510	340	2,560
180	660	490	350	2,570

2. Ottumwa Lagoon, Description and History

2.1 The Lake

Ottumwa Lagoon was originally a river oxbow that was impounded in the late 1950's in conjunction with channel modifications to the Des Moines River for flood control and hydroelectric power. The lake is located within the City of Ottumwa, in the southeast part of the state. Public use for Ottumwa Lagoon is estimated at approximately 94,000 visitors per year. Several ponds, municipal park facilities and the Beach Ottumwa, a municipal water recreation park, are located adjacent to the lake. Due to the presence of two combined sewer overflows (CSOs) that discharge to an upstream section of the lake, swimming in the lake at the water park has not been allowed and the use of recreational water craft (e.g. kayaks and paddle boats) on the lake at the park will be discontinued indefinitely as of the 2005 recreational season.

The City of Ottumwa has infrequently used the lake as an alternate drinking water source when nitrate levels in the Des Moines River have been elevated. However, the City is currently developing a new alternate water source, the Martin-Marietta lake north of Ottumwa. Construction of a new pumping station and transmission main for this source are scheduled to be complete by November, 2005.

Table 3. Ottumwa Lagoon Features

Waterbody Name:	Ottumwa Lagoon
Hydrologic Unit Code:	HUC10 0710000906
IDNR Waterbody ID:	IA 04-LDM-00215-L
Location:	Section 25 T72N R14W
Latitude:	41° 00' N
Longitude:	92° 25' W
Water Quality Standards Designated Uses:	1. Primary Contact Recreation (A1) 2. Aquatic Life Support (B(LW))
Tributaries:	Kettle Creek, Unnamed Creek
Receiving Waterbody:	Des Moines River
Lake Surface Area:	70 acres
Maximum Depth:	12 feet
Mean Depth:	6.7 feet
Volume:	467 acre-feet
Length of Shoreline:	18,900 feet
Watershed Area:	2,300 acres
Watershed/Lake Area Ratio:	33:1
Estimated Detention Time:	0.24 years

Morphometry

Ottumwa Lagoon has a mean depth of 6.7 feet and a maximum depth of 12 feet. The lake has a surface area of 70 acres and a volume of approximately 467 acre-feet. Temperature and dissolved oxygen sampling indicate that the lake does not stratify during the growing season.

Hydrology

Ottumwa Lagoon is fed by Kettle Creek and an unnamed creek. The City also maintains a control structure and pipeline that can transfer water from the Des Moines River to the lake. The lake discharges to the Des Moines River from a gated outlet. The estimated annual average detention time for the lake is 0.24 years based on outflow during natural conditions (i.e. when water from the Des Moines River is not fed to the lake through the inflow control structure). The methodology and calculations used to determine the detention time are shown in Appendix A.

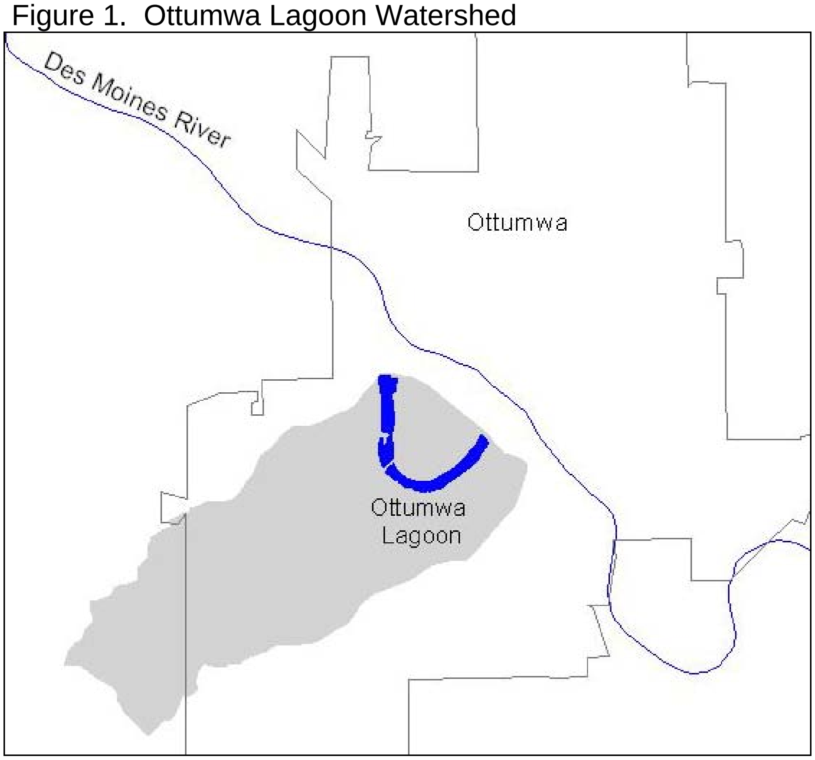
2.2 The Watershed

The Ottumwa Lagoon watershed has an area of approximately 2,300 acres (including the lake area) and has a watershed to lake ratio of 33:1. The 2002 landuses and associated areas for the watershed were obtained from satellite imagery and are shown in Table 4. The 2002 watershed landuse map is shown in Appendix D. Figure 1 shows the location and extents of the watershed.

Table 4. 2002 Landuse in Ottumwa Lagoon Watershed

Landuse	Area in Acres	Percent of Total Area
Grassland	740	32.2
Urban	640	27.8
Forest	420	18.3
Roads	170	7.4
Water/Wetland	160	7.0
Alfalfa	140	6.1
Row Crop	30	1.3
Total	2,300	100

Figure 1. Ottumwa Lagoon Watershed



The watershed is predominately gently sloping (2-14%) with prairie and forest-derived soils developed from alluvium, loess and till. The watershed includes 28 different soil types with Pershing, Landes-Perks-Nodaway and Humeston-Vesser-Colo soils comprising the majority of the area in the watershed.

3. TMDLs for Algae, Turbidity and Chlordane

3.1 TMDL for Algae and Turbidity

3.1.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Iowa Water Quality Standards (8) list the designated uses for Ottumwa Lagoon as Primary Contact Recreational Use (Class A1) and Aquatic Life (Class B(LW)). In 1998 the lake was included on the impaired waters list as “not supporting” designated Class A uses due to observance of combined sewer overflows (CSOs) discharging into the lake by DNR staff in June 1995.

In 2002, Class A uses were assessed as “partially supported”. Class B uses were assessed as partially supported. These assessments were based upon the 2000-01 ISU lakes survey, an ISU report on lake phytoplankton, and information from the DNR Fisheries Bureau. The lake was included on the 2002 impaired waters list for algae and turbidity.

For the 2004 assessment cycle both Class A and Class B designated uses have been assessed as “not supported” based on the 2000-02 ISU lakes survey, ISU plankton sampling and information from the DNR Fisheries Bureau. The lake was again included on the 2004 impaired waters list for algae and turbidity.

The primary monitored threat to Class A recreational uses is the presence of aesthetically objectionable blooms of algae, limited water clarity and the presence of nuisance algal species. Flow monitoring data for September 2002 through March 2005 from the Ottumwa Water Pollution Control Facility indicate that CSOs continue to discharge significant volumes of combined storm water and raw wastewater to the lake. However, neither bacterial monitoring of the CSO discharges nor in-lake bacterial monitoring is currently available to assess the status of the lake with respect to E. coli water quality standards (567 IAC 61.3(3)) or the impact of the discharges with respect to E. coli criteria. The monitored hyper-eutrophic conditions at Ottumwa Lagoon, along with information from the IDNR Fisheries Bureau, suggest that the Class B(LW) aquatic life uses are “not supported” due to excessive nutrient loading to the water column, nuisance blooms of algae, and organic enrichment.

The Iowa Water Quality Standards (8) do not include numeric criteria for nutrients but they do include narrative standards that are applicable to Ottumwa Lagoon stating that “such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor, or other aesthetically objectionable conditions.”

Data Sources

Water quality surveys have been conducted on Ottumwa Lagoon in 1979, 1990, and 2000-04 (1,2,3,4,5,20,21). Data from these surveys is available in Appendix B.

Iowa State University Lake Study data from 2000 to 2004 were evaluated for this TMDL. The ISU study was completed in 2004 and approximates a sampling scheme used by Roger Bachmann in earlier Iowa lake studies. Samples are collected at one location (maximum depth) three times during the early, middle, and late summer. A number of water quality parameters are measured including Secchi disk depth, phosphorus series, nitrogen series, TSS, and VSS.

Interpreting Ottumwa Lagoon Water Quality Data

Based on mean values from ISU sampling during 2000 - 2004, the ratio of total nitrogen to total phosphorus for the lake is 8:1. Data on inorganic suspended solids from the ISU survey indicate that the lake is subject to high levels of non-algal turbidity. The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey for 2000 - 2002 was 4.8 mg/l. The median level of inorganic suspended solids at Ottumwa Lagoon during the same time period was 27.1 mg/l, the 4th highest of the 131 lakes. Much of the suspended inorganic material in the water column of Ottumwa Lagoon is believed due to a large population of rough fish that re-suspend sediments and nutrients during feeding and spawning activities.

Comparisons of the TSI values for chlorophyll, Secchi depth and total phosphorus for in-lake sampling indicate that despite very high chlorophyll levels, a non-phosphorus limitation to algal growth is present (see Figure 2 and Appendix C). Carlson (23) suggests that the mean TSI relationship shown in Figure 2 (TSI(TP) >TSI(CHL) = TSI(SD)) indicates that algae dominate light attenuation but some factor such as nitrogen limitation, zooplankton grazing or toxics limit algal biomass. Zooplankton sampling performed by ISU for 2000 - 2003 show relatively small populations of zooplankton species that graze on algae in the lake. Limited sampling for herbicides and metals conducted in 2001 and 2002, respectively, do not indicate toxic levels for any of the selected analytes. The non-phosphorus limitation may be attributable to light attenuation by periodic elevated levels of inorganic suspended solids, the presence of toxic substances for which there has been no in-lake sampling and/or the relatively low nitrogen to phosphorus ratio at this lake.

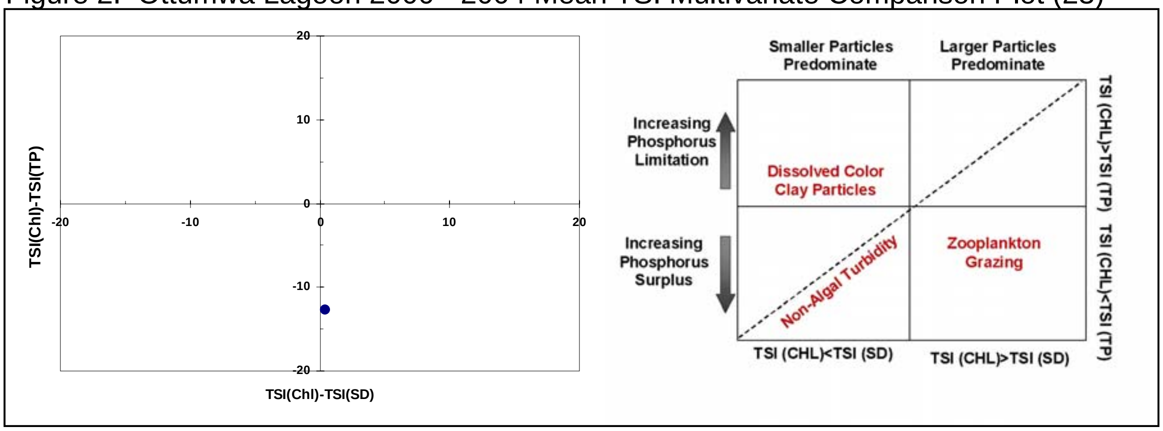
Based on the mean nitrogen to phosphorus ratio for 2000 - 2004 in-lake sampling, phosphorus is currently the limiting nutrient at Ottumwa Lagoon (N:P > 7.2 (32)). However, eight out of the fifteen individual samples indicate potential nitrogen limitation (N:P < 7.2). The low nitrogen to phosphorus ratio and any limitation it may impose on algal growth at the lake is likely due to the overabundance of phosphorus inputs. Also a reduction in nitrogen levels is unlikely to significantly curtail nuisance blooms of bluegreen algae due to their ability to fix atmospheric nitrogen. Therefore, phosphorus is the targeted pollutant of concern in this TMDL.

TSI values for 2000 - 2004 ISU monitoring data are shown in Table 5. TSI values for historical monitoring data and an explanation of Carlson's Trophic State Index are given in Appendix C.

Table 5. Ottumwa Lagoon TSI Values (3,4,5,20,21)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/29/2000	83	51	91
7/26/2000	83	56	81
8/16/2000	77	50	81
5/30/2001	73	77	90
6/27/2001	73	77	81
7/31/2001	73	84	86
6/5/2002	77	74	83
7/10/2002	77	81	86
8/7/2002	77	65	84
6/4/2003	50	59	89
7/9/2003	77	--	94
8/6/2003	77	62	87
6/2/2004	83	75	81
6/30/2004	77	71	84
8/4/2004	83	79	89

Figure 2. Ottumwa Lagoon 2000 - 2004 Mean TSI Multivariate Comparison Plot (23)



Data from ISU phytoplankton sampling for 2000 - 2004 indicate that bluegreen algae (Cyanophyta) dominate the summertime phytoplankton community of Ottumwa Lagoon. The number of available samples (three per summer) is insufficient to fully characterize the frequency of algal blooms. Sampling in 2000, 2001 and 2003 show moderate bluegreen algae populations relative to other Iowa lakes. However, sampling in 2002 and 2004 show very large blue-green algae blooms. Sampling for microcystin, a cyanotoxin associated with the *Mycrocystis* species of blue-green algae, was conducted in 2004. Iowa does not have water quality criteria for microcystin. The State of Nebraska utilizes a health alert threshold concentration of 15 ug/L. Microcystin concentrations in Ottumwa Lagoon were 1.0 ug/L, 2.5 ug/L and 12.6 ug/L for the 6/2/2004, 6/30/2004 and 8/4/2004 samples, respectively. Phytoplankton sampling results are given in Table B-7 of Appendix B.

Potential Pollution Sources

The potential phosphorus sources for Ottumwa Lagoon are point sources (CSOs and regulated storm water), nonpoint sources including atmospheric deposition and internal recycling of phosphorus and suspended solids from bottom sediments.

Natural Background Conditions

For the phosphorus load attributable to atmospheric deposition directly on the lake surface, the annual average concentration of phosphorus in precipitation was assumed to be 0.05 mg/L based on a review of available literature (11,17,18,19) and the default values used in the EUTROMOD and WILMS modeling programs. Contributions of phosphorus attributable to dry atmospheric deposition were not separated from the direct precipitation load. Potential phosphorus contributions from groundwater influx were not separated from the total source load.

3.1.2 TMDL Target

The Phase 1 targets of this TMDL are a TSI of less than 70 for total phosphorus, and TSI values of less than 65 for both chlorophyll a and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 96 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters.

Table 6. Ottumwa Lagoon Existing vs. Target TSI Values

Parameter	2000-2004 Mean TSI	2000-2004 Mean Value	Target TSI	Target Value	Minimum In-Lake Increase or Reduction Required
Chlorophyll	73	79 ug/L	<65	<33 ug/L	58% reduction
Secchi Depth	73	0.4 meters	<65	>0.7 meters	75% increase
Total Phosphorus	86	295 ug/L	<70	<96 ug/L	67% reduction

Criteria for Assessing Water Quality Standards Attainment

The State of Iowa does not have numeric water quality criteria for algae or turbidity. The algae and turbidity impairments are due to algal blooms caused by excessive nutrient loading to the lake and suspended solids. The nutrient loading objective is defined by a mean total phosphorus TSI of less than 70, which is related through the Trophic State Index to chlorophyll and Secchi depth. The TSI is not a standard, but is used as a guideline to relate phosphorus loading to the algae and turbidity impairment for TMDL development purposes and to describe water quality that will meet Iowa's narrative water quality standards. Inorganic suspended solids (i.e. non-algal turbidity) also contribute to lake turbidity. Since load reductions from phosphorus sources are expected to coincide with reductions in suspended solids loads the Phase 1 targeted pollutant is phosphorus. Future monitoring will determine if the targeted phosphorus reductions and corresponding reduction in suspended solids loading results in achievement of the TSI targets for chlorophyll and Secchi depth.

Selection of Environmental Conditions

The critical condition for which the TMDL TSI target values apply is the growing season (May through September). It is during this period that nuisance algal blooms are prevalent. The existing and target total phosphorus loadings to the lake are expressed as annual averages. Growing season mean (GSM) in-lake total phosphorus concentrations are used to calculate an annual average total phosphorus loading.

Modeling Approach

A number of different models that predict annual phosphorus load based on measured in-lake phosphorus concentrations were evaluated. In addition, watershed phosphorus delivery using both export coefficients and an annual loading function model as outlined in Reckhow's EUTROMOD User's Manual (10) was calculated. The results from both approaches were compared to select the best-fit empirical model.

Table 7. Model Results

Model	Predicted Existing Annual Total Phosphorus Load (lbs/yr) for in-lake GSM TP = ANN TP = 295 ug/L	Comments
Loading Function	3,230	Reckhow (10)
EPA Export	2,500	EPA/5-80-011
WILMS Export	2,390	"most likely" export coefficients
Reckhow 1991 EUTROMOD Equation	116,780	GSM model. Pin out of range.
Canfield-Bachmann 1981 Natural Lake	4,030	GSM model
Canfield-Bachmann 1981 Artificial Lake	10,050	GSM model
Reckhow 1977 Anoxic Lake	1,860	GSM model
Reckhow 1979 Natural Lake	4,050	GSM model. P out of range.
Reckhow 1977 Oxic Lake (z/Tw < 50 m/yr)	2,420	GSM model. P, Pin out of range.
Nurnberg 1984 Oxic Lake	3,230 (internal load = 180)	Annual model. P, L out of range.
Vollenweider 1982 Combined OECD	4,830	Annual model
Vollenweider 1982 Shallow Lake	5,020	Annual model
Walker Reservoir	9,950	GSM model. Pin out of range.
Simple First Order	2,170	Not calibrated to any lake data set
First Order Settling	1,960	Not calibrated to any lake data set
Walker Second Order	14,000	GSM model. Pin out of range.

The Nurnberg, Canfield-Bachmann Natural Lake, Reckhow Oxic, Reckhow Natural Lake, Simple First Order, First Order Settling and Reckhow Anoxic models resulted in values closest to the Loading Function and export estimates. The Simple First Order and First Order Settling models are simplified mechanistic models that have not been calibrated to a lake data set. Of the empirical models, only the Canfield-Bachmann and Reckhow Anoxic models are within the parameter ranges used to derive them when applied to Ottumwa Lagoon due to its high in-lake phosphorus levels. Ottumwa Lagoon is an oxic lake, making application of the Reckhow Anoxic Model questionable. The Reckhow Oxic, Simple First Order and First Order Settling models predict existing lake loadings significantly below the Loading Function estimate, which is believed to be the most accurate of the three watershed loading estimates. The Nurnberg, Canfield-Bachmann Natural Lake and Reckhow Natural Lake models return values that are similar and reasonably close to the Loading Function estimate.

The high phosphorus and inorganic suspended solids levels at Ottumwa Lagoon indicate the likelihood of a significant internal loading. The existing load predicted by the Nurnberg Model also indicates a significant internal load. Therefore, use of the Loading Function estimate with the Nurnberg Oxic Lake Model was selected as the basis for determining the existing load. The Nurnberg Model was also used to determine load targets as a function of the relative contribution from internal and external sources.

The equation for the Nurnberg Oxic Lake Model is:

$$P = \frac{L_{Ext}}{q_s}(1 - R) + \frac{L_{Int}}{q_s}$$

where

$$R = \frac{15}{18 + q_s}$$

$P =$ predicted in-lake total phosphorus concentration (ug/L)
$L_{Ext} =$ external areal total phosphorus load (mg/m^2 of lake area per year)
$L_{Int} =$ internal areal total phosphorus load (mg/m^2 of lake area per year)
$q_s =$ areal water loading (m/yr)

The Nurnberg Model represents a possible continuum of internal and external loads for a given in-lake total phosphorus concentration. The Loading Function Model external load estimate was used in combination with the Nurnberg Model to determine the existing loads as follows:

$$P = 295(\mu g / L) = \frac{5{,}172(mg / m^2)}{8.64(m / yr)}(1 - \frac{15}{18 + 8.64(m / yr)}) + \frac{288(mg / m^2)}{8.64(m / yr)}$$

An example of a load calculation for target internal and external loads of 50 and 950 pounds, respectively, is:

$$P = 87(\mu g / L) = \frac{1{,}526(mg / m^2)}{8.64(m / yr)}(1 - \frac{15}{18 + 8.64(m / yr)}) + \frac{80(mg / m^2)}{8.64(m / yr)}$$

The above calculation includes a margin of safety by using an in-lake concentration 10% below the desired endpoint (P < 96 ug/L) to calculate the target loads. The annual total phosphorus loads are obtained by multiplying the areal loads (L_{Ext}, L_{Int}) by the lake area in square meters and converting the resulting values from milligrams to pounds.

For the in-lake total phosphorus target and any selected target internal load, the corresponding target external load can be calculated from the relationship shown in Figure E-1 in Appendix E.

Waterbody Pollutant Loading Capacity

The chlorophyll a and Secchi depth objectives are related through the Trophic State Index to total phosphorus. The load capacity for this TMDL is the annual amount of phosphorus Ottumwa Lagoon can receive and meet its designated uses. The Phase 1 target TSI (TP) value is less than 70, or an in-lake total phosphorus concentration of less than 96 ug/L. For the selected lake response model, the target total load is a function of the relative internal and external load contributions as shown in Table 8.

3.1.3 Pollution Source Assessment

External phosphorus loading is attributable to a number of sources within the watershed. The primary external source categories are regulated storm water discharges, CSO discharges, nonpoint storm water runoff from areas not included in the City's MS4 permit, and atmospheric deposition directly on the lake surface.

Table 8. Ottumwa Lagoon Total Phosphorus Target

Total Phosphorus Target Loads (lbs/year)		
Internal	External	Total
0	1,070	1,070
10	1,040	1,050
20	1,020	1,040
30	1,000	1,030
40	980	1,020
50	950	1,000
60	930	990
70	910	980
80	880	960
90	860	950
100	840	940
110	820	930
120	790	910
130	770	900
140	750	890
150	720	870
160	700	860
170	680	850
180	660	840

Since the sewers in the urban portion of the watershed consist largely of combined storm water and wastewater, a portion of the load associated with urban storm water runoff is transported outside of the watershed to the municipal wastewater treatment plant. Also, a portion of the wastewater transported by the combined sewer system is delivered to the lake via the two CSO discharges. Separation of the urban storm water loads transported outside of the watershed by the combined sewer system and any storm water loads attributable to non-combined storm sewers within the watershed is problematic without more extensive monitoring data than is currently available. However, the City has monitored CSO discharge volumes from September 2002 through March 2005. For the purposes of estimating the existing load attributable to urban areas, it was assumed that the storm water load transported out of the watershed and that attributable to non-combined sewer discharges into the lake were roughly equivalent, resulting in a net loading of zero from non-combined urban storm water to the lake. Water quality monitoring data for the CSO discharges was not available and the total phosphorus load from this source was estimated using a literature-based (28) typical CSO concentration of 2 mg/L in conjunction with the monitored discharge volumes.

Existing non-urban watershed loads were estimated using the Loading Function methodology as described by Reckhow (10). The load from atmospheric deposition on the lake surface was estimated as previously described in Section 3.1.1, *Natural Background Conditions*.

Internal phosphorus loading at the lake is the result of resuspension of sediments by rough fish and lake wind and wave action. The existing internal phosphorus load was estimated using the Nurnberg Oxic Lake Model, which explicitly accounts for an internal loading component.

Potential load contributions or losses from groundwater influx/efflux were not separated from the total point and nonpoint source loads.

Existing Load

The annual total phosphorus load to Ottumwa Lagoon is estimated to be 3,410 pounds per year based on the Loading Function and Nurnberg Oxic Lake models. This estimate includes 1,900 pounds per year from CSO discharges, 1,300 pounds per year from non-urban sources, 180 pounds per year from internal loading, and 30 pounds per year from atmospheric deposition.

From modeling using the Revised Universal Soil Loss Equation (RUSLE), the existing sediment loading from the watershed is estimated to be 840 tons per year. In addition, the suspended solids contribution (including both inorganic and organic suspended solids) of the CSO discharges is estimated to be 190 tons per year assuming a literature-based (28) typical CSO concentration of 400 mg/L.

Departure from Load Capacity

Table 9 shows the load reductions necessary to achieve and maintain Phase 1 water quality goals.

Table 9. Ottumwa Lagoon Load Reductions to Meet Phase 1 Goals

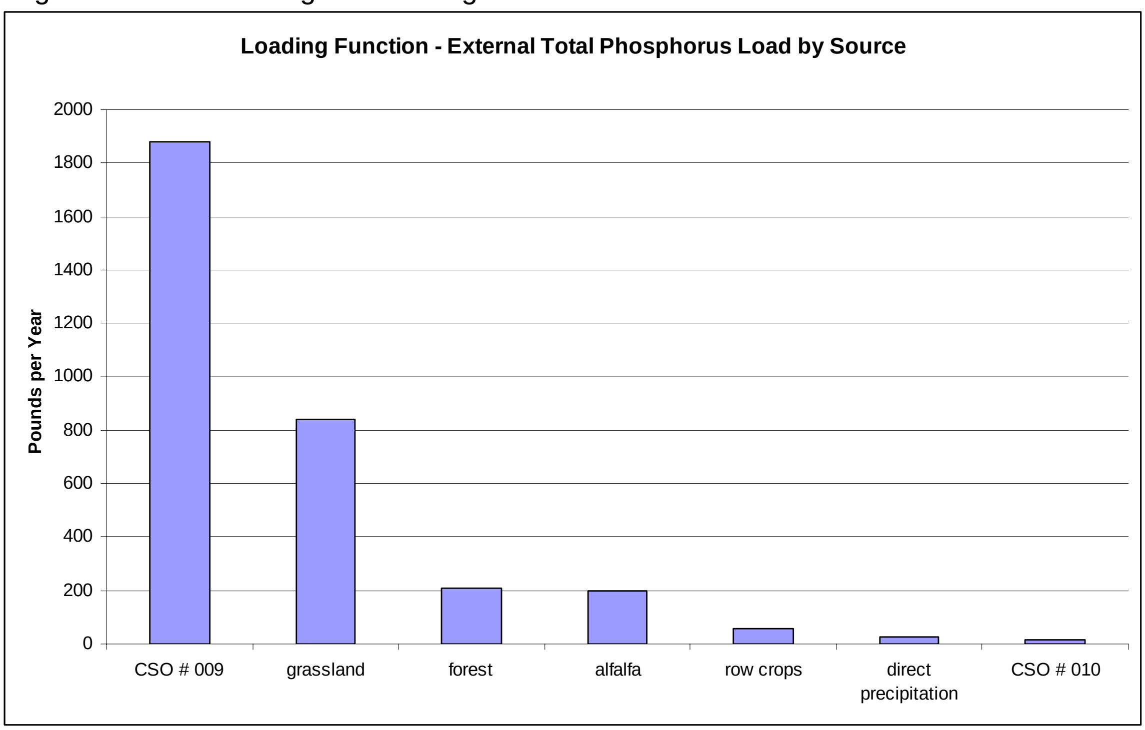
Total Phosphorus Loads (lbs/year)		Required Load Reduction (lbs/year)
Internal	External	
0	1,070	2,340
10	1,040	2,360
20	1,020	2,370
30	1,000	2,380
40	980	2,390
50	950	2,410
60	930	2,420
70	910	2,430
80	880	2,450
90	860	2,460
100	840	2,470
110	820	2,480
120	790	2,500
130	770	2,510
140	750	2,520
150	720	2,540
160	700	2,550
170	680	2,560
180	660	2,570

Identification of Pollutant Sources

From the Loading Function Model, the largest source of phosphorus delivered to the lake is from CSO # 009 (Richmond Avenue Pump Station CSO) as shown in Figure 3. The Loading Function Model also indicates significant loads from grassland, forest and alfalfa landuses. It should be noted that while the Loading Function Model provides estimates of the primary potential pollutant sources and a means of estimating existing internal versus external loads, the existing and target total loads identified in this TMDL are independent of the Loading Function Model. The Loading Function Model was used only for comparison purposes to select an empirical lake response model and to separate the existing total load predicted by the lake response model into internal and external components. Existing and target loads were calculated from measured and target in-lake total phosphorus concentrations using the selected lake response model as shown in *Section 3.2, Modeling Approach.* Also, the Loading Function Model estimates only external watershed phosphorus inputs and does not account for internal loading.

The Nurnberg Model indicates that internal loading makes up approximately 5% of the existing total phosphorus mass loading to the lake. However, the internal load has a greater effect on in-lake total phosphorus concentrations on a pound for pound basis. The model relationship shows that one pound of internal loading is equivalent to 2.3 pounds of external loading. In terms of lake response, the internal load is estimated to comprise approximately 11% of the total load.

Figure 3. Ottumwa Lagoon Loading Function Model Source Contributions



Other sources of phosphorus capable of being delivered to the water body exist. Manure and waste from wildlife, pets, etc. also contribute to the phosphorus loading. Unfortunately, the potential phosphorus being contributed from these sources is difficult to quantify. These potential sources have been considered, but are deemed smaller contributors or have less impact than the sources previously identified. However, these sources will be evaluated and quantified as required in Phase 2 of this TMDL.

Linkage of Sources to Target

The phosphorus load to Ottumwa Lagoon originates from regulated storm water discharges, CSO discharges, nonpoint storm water runoff from areas not included in the City's MS4 permit, atmospheric deposition directly on the lake surface and internal recycling. To meet the TMDL endpoint, the total source contribution needs to be reduced as shown previously in Table 9.

3.1.4 Pollutant Allocation

Wasteload Allocation

The combined sewers and associated CSOs that discharge to Ottumwa Lagoon are scheduled to be separated by October 2013. Therefore, the Wasteload Allocation (WLA) for these sources will be set at zero. However, following the sewer separation, storm water from the areas covered under the City's MS4 permit will continue to contribute significant flows to the lake. Currently, approximately 1,730 acres of the watershed area is included in the City's corporate limits. To account for potential future development and expansion in the area, the wasteload allocation for this TMDL has been determined as a function of the drainage area included in the MS4 permit as follows:

WLA (lbs/year) = $\left(\dfrac{L_{Ext} - L_{Precip}}{DA_{Total}}\right) \times A_{MS4}$

where

L_{Ext} = external total phosphorus target load (lbs/year)
L_{Precip} = direct precipitation load = 30 lbs/year
DA_{Total} = watershed drainage area excluding the lake surface = 2,230 acres
A_{MS4} = area included in the City's MS4 permit excluding the lake surface (acres)

For the existing MS4 area of 1,730 acres, the WLA values are shown in Table 10.

Load Allocation

The Load Allocation (LA) for this TMDL is also a function of the watershed drainage area included in the City's MS4 permit and is given by:

LA (lbs/year) = $L_{Int} + L_{ext}$ - WLA

where

L_{Int} = internal total phosphorus target load (lbs/year)
L_{Ext} = external total phosphorus target load (lbs/year)

For the existing MS4 area of 1,730 acres, the LA values are as shown in Table 10.

Table 10. Ottumwa Lagoon Wasteload and Load Allocations

Total Phosphorus Loads (lbs/year)		WLA (lbs/year)	LA (lbs/year)
Internal	External		
0	1,070	810	260
10	1,040	790	260
20	1,020	770	270
30	1,000	750	280
40	980	740	280
50	950	720	280
60	930	700	290
70	910	680	300
80	880	660	300
90	860	650	300
100	840	630	310
110	820	610	320
120	790	590	320
130	770	580	320
140	750	560	330
150	720	540	330
160	700	520	340
170	680	510	340
180	660	490	350

Margin of Safety

The target total phosphorus loads are calculated using an in-lake concentration 10% below the desired endpoint to ensure that the required load reduction will result in attainment of water quality targets.

3.1.5 Algae and Turbidity TMDL Summary

This TMDL accounts for potential variation in both internal phosphorus loading and in the area covered by the City of Ottumwa's MS4 NPDES permit. The TMDL, wasteload allocation and load allocation values vary accordingly. An example of the TMDL equation for an internal loading target value of 50 pounds per year and the existing NPDES-permitted area of 1,730 acres is:

TMDL = Load Capacity (1,000 lbs/year) = WLA (720 lbs/year) + LA (280 lbs/year) + MOS (implicit)

3.2 TMDL for Chlordane

3.2.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Iowa Water Quality Standards (8) state that Class B waters "shall contain no substances in concentrations which will make fish or shellfish inedible due to undesirable tastes or cause a hazard to humans after consumption" (567 IAC 61.3(3)). Regional Ambient Fish Tissue (RAFT) monitoring conducted in 1998 at Ottumwa Lagoon showed levels of technical in composite samples of common carp as 0.39 mg/kg. Follow-up RAFT monitoring in 1999 showed levels of technical chlordane for carp and channel catfish as 0.24 mg/kg and 0.32 mg/kg, respectively. The Food and Drug Administration (FDA) action level for chlordane in fish is 0.30 mg/kg. The RAFT sampling values found in 1998 and 1999 resulted in assessment of fish consumption uses for Ottumwa Lagoon as “fully supported/threatened” for the year 2000 assessment cycle.

In 2002, fish consumption uses were assessed as “not supported” due to RAFT monitoring in 2000 that showed levels of technical chlordane in channel catfish of 0.87 mg/kg. The lake was included on the 2002 impaired waters list for chlordane and a fish consumption advisory was issued in 2001.

For the 2004 assessment cycle fish consumption uses have been assessed as “not supported” based on the results of the RAFT monitoring conducted in 2000 and 2002. While levels of technical chlordane found in carp fillets were below the FDA action level, the level found in composite channel catfish samples was 0.78 mg/kg and the fish consumption advisory remains in effect. The lake has been placed on the 2004 impaired waters list for chlordane.

Chlordane is an organochlorine insecticide. It is very persistent in the environment, yet very insoluble in water. Noted potential adverse health effects of chlordane associated with long-term exposure are damage to the liver, kidneys, heart, lungs, spleen, adrenal glands and cancer. The Iowa Water Quality Standards (8) limit for chlordane *in water* related to human health protection associated with fish consumption is 0.006 micrograms per liter. However, elevated chlordane levels in water have not been a noted problem in Iowa waters. Chlordane attaches to sediments and bioaccumulates in fish, most notably in bottom-feeding species such as carp and channel catfish.

The FDA has set an action level for chlordane in fish tissue of 0.30 mg/kg, which is used as the numerical criteria for assessment of the chlordane impairment and issuance of the fish consumption advisory. This action level was developed to provide chronic health protection for potential risks due to a lifetime of consumption of contaminated fish.

Data Sources

RAFT monitoring has been conducted at Ottumwa Lagoon in 1998, 1999, 2000, 2001 and 2002. Data from this monitoring is shown in Appendix B.

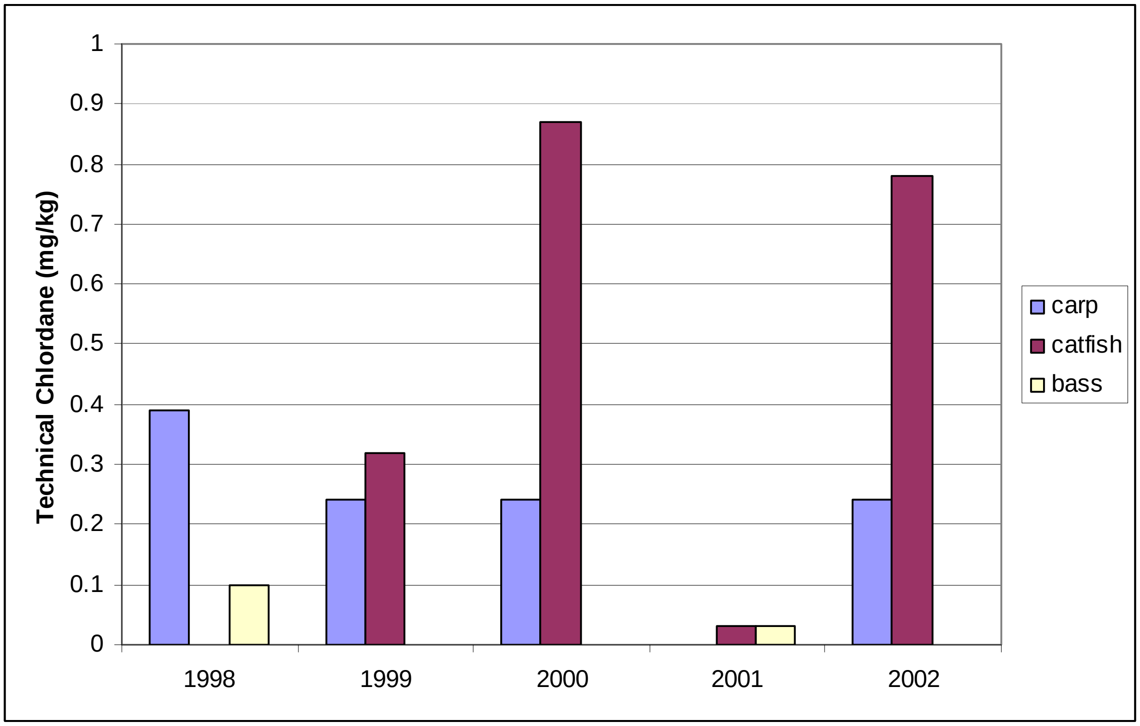
Interpreting Ottumwa Lagoon Water Quality Data

RAFT monitoring data for 1998 through 2002 is shown in Figure 4. Chlordane degrades slowly in the environment and its commercial use was banned by the EPA in 1988. Therefore, levels in fish tissue are expected to gradually decline over time.

Potential Pollution Sources

In the mid 1970’s, the major use of chlordane in Iowa was for pest control, primarily for termites and for home lawn and garden use. In addition, there were small amounts of chlordane used for agricultural purposes (29). Between July 1, 1983 and April 14, 1988, the sole use of chlordane was to control subterranean termites (30). For this purpose, chlordane was applied primarily as a liquid that was poured or injected around a building foundation (31). Historical chlordane loading to the lake most likely originated from urban and agricultural runoff from areas where chlordane was used as an insecticide, as well as through basement sump/foundation drain connections that may be connected to the combined sewer system and associated CSOs that discharge to the lake. In response to potential health effects from chlordane exposure, commercial use of chlordane was banned in April, 1988. Therefore no further loading to the lake should occur.

Figure 4. Ottumwa Lagoon RAFT Sampling Results



Natural Background Conditions

Chlordane is an anthropogenic pollutant. There are no naturally occurring sources of chlordane.

3.2.2 TMDL Target

Criteria for Assessing Water Quality Standards Attainment

The target for this TMDL is to achieve two consecutive samples with all fish tissue chlordane levels below the FDA action level of 0.30 mg/kg. Once this target is met, the IDNR will evaluate whether or not the fish consumption advisory should be lifted.

Selection of Environmental Conditions

The target for this TMDL is a not-to-exceed numeric fish tissue concentration, which is independent of seasonal or other variations in environmental conditions.

Waterbody Pollutant Loading Capacity

The use of chlordane has been banned. Therefore, the loading capacity for this TMDL has been set at zero.

3.2.3 Pollution Source Assessment

Existing Load

Due to the ban of its use, no additional chlordane is being introduced into the environment. The existing watershed load is estimated as zero.

Departure from Load Capacity

Chlordane contamination at Ottumwa Lagoon is the result of historical loads that have ceased since its ban. The pollutant loading capacity has been set at zero. The existing watershed load is also estimated as zero.

Identification of Pollutant Sources

There are no identified current sources of chlordane other than contaminated sediments that are the result of historical loads.

Linkage of Sources to Target

As discussed previously, there are no known current sources of chlordane. It is expected that chlordane levels in fish tissue will decline slowly over time as natural transport and biotransformation processes occur within the lake.

3.2.4 Pollutant Allocation

Wasteload Allocation

There will be no discharge of chlordane from point sources into Ottumwa Lagoon. Therefore, the Wasteload Allocation (WLA) for this TMDL is zero.

Load Allocation

There will be no further application of chlordane in the watershed. The Load Allocation (LA) for this TMDL is zero.

Margin of Safety

An implicit margin of safety is included in that two consecutive samples with all fish tissue chlordane levels below the FDA action level will be required to meet the TMDL endpoint.

3.2.5 Chlordane TMDL Summary

The equation for the total maximum daily load is:

TMDL = Load Capacity (0) = WLA (0) + LA (0) + MOS (implicit)

4. Implementation Plan

The following implementation plan is not a required component of a Total Maximum Daily Load but can provide department staff, partners, and watershed stakeholders with a strategy for improving Ottumwa Lagoon water quality.

4.1 Algae and Turbidity

The algae and turbidity impairments at Ottumwa Lagoon are a result of excessive phosphorus and suspended solids loadings to the lake. The primary mechanism by which phosphorus is transported to surface waters is by movement with particulate matter, or suspended solids, in water. Management practices that reduce phosphorus delivery should also reduce suspended solids loading. Therefore, phosphorus is the targeted pollutant of concern and is related through the Trophic State Index to algae and turbidity. Ottumwa Lagoon receives phosphorus loading from regulated storm water discharges, combined sewer overflows, runoff from nonpoint sources, atmospheric deposition, and internal recycling of phosphorus from the lake bottom sediments.

Combined sewer overflows are estimated to be the largest source of phosphorus loading to the lake. Both of the overflows that enter the lake are scheduled to be separated by October 2013. Separation of the sewers will eliminate that portion of the phosphorus loading attributable to raw wastewater, but not loads due to urban storm water runoff. Sewer separation will also remove suspended solids loads associated with the raw wastewater.

Among the potential mechanisms of internal loading are resuspension of bottom sediments from bottom feeding rough fish such as carp, and wind-driven waves and currents. The internal load at Ottumwa Lagoon is believed to be due in large part to the abundance of bottom-feeding rough fish. However, it should be noted that any sediment-attached phosphorus that is recycled within the lake ultimately originated from watershed sources. Significant historical sediment loading to the lake is apparent from inspection of the lake bathymetry and aerial photos, particularly in the area where Kettle Creek enters the lake.

With much of the watershed devoted to urban land uses Best Management Practices (BMPs) for controlling phosphorus delivery associated with urban runoff are of particular importance in the Ottumwa Lagoon watershed. Suggested BMPs for both urban and rural residential land uses include:

- Addition of landscape diversity to reduce runoff volume and/or velocity through the strategic location of filter strips, rain gardens and grass waterways, etc.
- Installation of terraces, ponds, or other erosion and water control structures at appropriate locations within the watershed to control erosion and reduce delivery of sediment and phosphorus to the lake.
- Use of low or no-phosphorus fertilizers on residential and commercial lawns.
- Use of appropriate erosion controls on construction sites to reduce delivery of sediment and phosphorus to the lake.

For agricultural land uses, suggested BMPs include the following:

- Nutrient management on production agriculture ground to achieve the optimum soil test category. This soil test category is the most profitable for producers to sustain in the long term.
- Incorporate or subsurface apply phosphorus (manure and commercial fertilizer) while controlling soil erosion. Incorporation will physically separate the phosphorus from surface runoff.
- Continue encouraging the adoption of reduced tillage systems, specifically no till and strip tillage.
- Initiate a fall-seeded cover crop incentive program. Target low residue producing crops (e.g. soybeans) or low residue crops after harvest (e.g. corn silage fields). This practice increases residue cover on the soil surface and improves water infiltration.
- Use rotational grazing systems and provide limited cattle access to streams. These practices reduce upland erosion, streambank erosion and associated sediment-attached phosphorus delivery.

Internal loading can be controlled through fish management to control rough fish (i.e., carp) and dredging to remove nutrients from the lake system.

Reductions in watershed loads will require significant infrastructure improvements and management practices that will take significant funding and time to implement. The estimated cost for sewer separation in the southern portion of Ottumwa is in excess of 26 million dollars. Since the contribution of the CSO discharges is a primary source of phosphorus to the lake, the sewer separation schedule is critical in establishment of a schedule for reductions in overall loading. The following timetable is suggested for reduction of phosphorus inputs:

- Reduce watershed and recycle loading from 3,400 pounds per year to 2,400 pounds per year by 2013.
- Reduce watershed and recycle loading from 2,400 pounds per year to 1,700 pounds per year by 2018.
- Reduce watershed and recycle loading from 1,700 pounds per year to 1,000 pounds per year by 2023.

The final target of 1,000 pounds per year assumes that reductions in internal and external loads will be roughly proportional. It should be noted that the final total target load may vary depending upon the internal and external load reductions achieved as shown in previous sections of this report.

The CSO separation schedule will be enforced through the City's wastewater NPDES permit. In addition, the City of Ottumwa's NPDES MS4 permit requires development of a Storm Water Pollution Prevention & Management Program (SWMP). The SWMP includes requirements for implementation of BMPs including controls to reduce pollutants in discharges from municipal application of fertilizers and operation of a public education and outreach program to inform the public of storm water impacts on water quality and measures that can be implemented to reduce water quality degradation from storm water. As recommended by the EPA, the WLA for phosphorus will be implemented through the NPDES MS4 permit and will attempt to utilize best management practices in lieu of numeric limits.

Reasonable Assurance

To meet the algae and turbidity water quality targets in this TMDL, wasteload and load allocations requiring pollutant reductions from both point and nonpoint sources have been established. To ensure water quality targets are met, there must be reasonable assurance that both point and nonpoint sources contributing to the water quality problems in Ottumwa Lagoon will be addressed. For point sources, this assurance is provided through NPDES permits issued for point source discharges. Federal regulations require effluent limits for an NPDES permit to be consistent with the requirements of any available wasteload allocation for a given discharge prepared by the state and approved by EPA. In the case of Ottumwa Lagoon, the CSO discharges to the lake are to be eliminated through construction projects that will separate storm and sanitary sewers. Following sewer separation, the separate storm sewer discharges will be regulated through the City's NPDES MS4 permit.

For load allocations for nonpoint sources, a number of mechanisms are available for implementing BMPs. Section 319 grant funding from the federal Clean Water Act is administered by the IDNR's Nonpoint Source Management Program and available to support NPS projects conducted by cooperating agencies such as universities, other state agencies, organizations and soil and water conservation districts (SWCDs). The Iowa Water Protection Fund (WPF) and Watershed Protection Fund (WSPF) provide funding support to water quality projects sponsored by SWCDs. The Environmental Quality Incentives Program (EQIP) is a USDA conservation cost-share program designed to encourage and support voluntary conservation of natural resources on private agricultural lands. It provides technical assistance, cost-share and incentive payments, and education to producers. These funds are often used in conjunction with 319 and WPF water quality projects as incentives for private landowners.

Through monitoring and assessment of water quality in response to the implementation of both point and nonpoint source controls, decisions on additional actions necessary to ensure the water quality targets are met can be made and incorporated into Phase II of this TMDL. The City of Ottumwa, state and federal agencies, and local watershed groups or individuals would be expected to play the major part in this strategy of adaptive management of the watershed.

4.2 Chlordane

Since chlordane has been banned, there is no specific remediation plan for this impairment. The fish consumption advisory for chlordane will be continued until monitoring data confirms that fish tissue chlordane levels have declined below the FDA action level.

5. Monitoring

Further monitoring is needed at Ottumwa Lagoon to follow-up on the implementation of the TMDLs. Monitoring for parameters associated with the algae and turbidity impairments will, at a minimum, meet the minimum data requirements established by Iowa's 305(b) guidelines for a complete water quality assessment (3 lake samples per year over 3 years, 10 lake samples over 2 years, etc.). This data will be collected by 2010. Follow-up RAFT monitoring for chlordane in fish tissue will continue on a biennial basis until at least two consecutive samples are below the FDA action level and until at least one year of sampling indicates levels below ½ of the FDA action level.

6. Public Participation

A public information meeting regarding ongoing TMDL development for Ottumwa Lagoon was held May 18, 2005 at Ottumwa City Hall. A second public meeting will be held to present the draft TMDL to the public in the fall of 2005. Comments received were reviewed and, where appropriate, incorporated into the TMDL.

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8. Appendix A - Lake Hydrology

General Methodology

Purpose

There are approximately 127 public lakes in Iowa. The contributing watersheds for these lakes range in area from 0.028 mi^2 to 195 mi^2 with mean and median values of 10 mi^2 and 3.5 mi^2, respectively. Few, if any, of these lakes have gauging data available to determine flow statistics for the tributaries that feed into them. A select few have some type of stage information that may be useful in determining historical discharge from the lake itself.

With the large number of lakes on the State's 303(d) list and the requirement for rapid development of TMDLs for these lakes, it was realized that a method to quickly estimate flow statistics for required lake response model inputs would be desirable. In an attempt to achieve this goal, flow data and watershed characteristics for a number of USGS gauging stations with small contributing watershed areas were compiled and evaluated via both simple and multiple linear regressions. The primary focus of this evaluation was estimation of the average annual flow statistic for input to empirical lake response models. However, regression equations for monthly average and calendar year flow statistics were also developed that may be of additional use.

It should be noted that attempts were made to develop regression equations for low-flow streamflow statistics (1Q10, 7Q10, 30Q10, 30Q5 and harmonic mean) but the relationships derived were for the most part considered too weak (R^2 adj.< 70%) to be of practical use. One exception to this is the 30Q5 statistic, which gave an R^2 adj. of 85%. In addition, regression equations were developed for monthly flow prediction models for two months (January and May). Once again, the relationships did not exhibit a high level of correlation and due to the large amount of data required to develop these models, development of equations for additional months was not attempted.

Data

Flow data and watershed characteristics from 26 USGS gauging stations were used to derive the regression equations. The ranges of basin characteristics used to develop the regression equations are shown in Table A-1.

Drainage areas were taken directly from USGS gauge information available at http://water.usgs.gov/waterwatch/ . Precipitation values were obtained through the Iowa Environmental Mesonet IEM Climodat Interface at http://mesonet.agron.iastate.edu/climodat/index.phtml . Where weather and gauging stations were not located in the same town, precipitation information was obtained from the weather station located in the town with the shortest straight-line distance from the gauging station.

Average basin slope and land cover percentages were determined using Arc View and statewide coverages clipped within HUC-12 sub-watersheds. It should be noted that the smallest basin coverages used in determining land cover percentages and average basin slopes were single HUC-12 units (i.e. no attempt was made to subdivide HUC-12 basins into smaller units where the drainage area was less than the area of the HUC-12 basin). Therefore, the regression models assume that for very small watersheds the land cover percentages of the HUC-12 basin are representative of the watershed located within the basin.

The Hydrologic Region for each station was determined from Figure 1 of USGS Water-Resources Investigation Report 87-4132, Method for Estimating the Magnitude and Frequency of Floods at Ungaged Sites on Unregulated Rural Streams in Iowa. None of the stations included in the analyses were located in Regions 1 or 5. This is reflected in the regression equations developed that utilize the hydrologic region as a variable.

Table A-1. Ranges of Basin Characteristics Used to Develop the Regression Equations

Basin Characteristic	Name in equations	Minimum	Mean	Maximum
Drainage Area (mi^2)	DA	2.94	80.7	204
Mean Annual Precip (inches)	$\overline{P}_A$	26.0	34.0	36.2
Average Basin Slope (%)	S	1.53	4.89	10.9
Landcover - % Water	W	0.020	0.336	2.80
Landcover - % Forest	F	2.45	10.3	29.9
Landcover - % Grass/Hay	G	9.91	31.3	58.7
Landcover - % Corn	C	6.71	31.9	52.3
Landcover - % Beans	B	6.01	23.1	37.0
Landcover - % Urban/Artificial	U	0	2.29	7.26
Landcover - % Barren/Sparse	B'	0	0.322	2.67
Hydrologic Region	H	Regions 1 - 5 used for delineation but data for USGS stations in Regions 2, 3 & 4 only.		

Methods

Simple regression models were developed for annual average and monthly average statistics with drainage area as the sole explanatory variable. Multiple linear regression models considering all explanatory variables were developed utilizing stepwise regression in Minitab. All data with the exception of the Hydrologic Region were log transformed. Explanatory variables with regression coefficients that were not statistically different from zero (p-value greater than 0.05) were not utilized.

Equation Variables

Table A-2. Regression Equation Variables

Annual Average Flow (cfs)	$\overline{Q}_A$
Monthly Average Flow (cfs)	$\overline{Q}_{MONTH}$
Annual Flow – calendar year (cfs)	Q_{YEAR}
Drainage Area (mi^2)	DA
Mean Annual Precip (inches)	$\overline{P}_A$
Mean Monthly Precip (inches)	$\overline{P}_{MONTH}$
Antecedent Mean Monthly Precip (inches)	$\overline{A}_{MONTH}$
Annual Precip – calendar year (inches)	P_{YEAR}
Antecedent Precip – calendar year (inches)	A_{YEAR}
Average Basin Slope (%)	S
Landcover - % Water	W
Landcover - % Forest	F
Landcover - % Grass/Hay	G
Landcover - % Corn	C
Landcover - % Beans	B
Landcover - % Urban/Artificial	U
Landcover - % Barren/Sparse	B′
Hydrologic Region	H

Equations

Table A-3. Drainage Area Only Equations

Equation	**R^2 adjusted (%)**	**PRESS (log transform)**
$\overline{Q}_A = 0.832DA^{0.955}$	96.1	0.207290
$\overline{Q}_{JAN} = 0.312DA^{0.950}$	85.0	0.968253
$\overline{Q}_{FEB} = 1.32DA^{0.838}$	90.7	0.419138
$\overline{Q}_{MAR} = 0.907DA^{1.03}$	96.6	0.220384
$\overline{Q}_{APR} = 0.983DA^{1.02}$	93.1	0.463554
$\overline{Q}_{MAY} = 1.97DA^{0.906}$	89.0	0.603766
$\overline{Q}_{JUN} = 2.01DA^{0.878}$	88.9	0.572863
$\overline{Q}_{JUL} = 0.822DA^{0.977}$	87.2	0.803808
$\overline{Q}_{AUG} = 0.537DA^{0.914}$	74.0	1.69929
$\overline{Q}_{SEP} = 0.123DA^{1.21}$	78.7	2.64993
$\overline{Q}_{OCT} = 0.284DA^{1.04}$	90.2	0.713257
$\overline{Q}_{NOV} = 0.340DA^{0.999}$	89.8	0.697353
$\overline{Q}_{DEC} = 0.271DA^{1.00}$	86.3	1.02455

Table A-4. Multiple Regression Equations

Equation	**R^2 adjusted (%)**	**PRESS (log transform)**
$\overline{Q}_A = 1.17 \times 10^{-3} DA^{0.998} \overline{P}_A^{\,1.54} S^{-0.261} (1+F)^{0.249} C^{0.230}$	98.7	0.177268 (n=26)
$\overline{Q}_{JAN} = 0.213 DA^{0.997} \overline{A}_{JAN}^{\,0.949}$	89.0	0.729610 (n=26;same for all $\overline{Q}_{MONTH}$)
$\overline{Q}_{FEB} = 2.98 DA^{0.955} \overline{A}_{FEB}^{\,0.648} G^{-0.594} (1+F)^{0.324}$	97.0	0.07089
$\overline{Q}_{MAR} = 6.19 DA^{1.10} B^{-0.386} G^{-0.296}$	97.8	0.07276
$\overline{Q}_{APR} = 1.24 DA^{1.09} \overline{A}_{APR}^{\,1.64} S^{-0.311} B^{-0.443}$	97.1	0.257064
$\overline{Q}_{MAY} = 10^{(-3.03+0.114H)} DA^{0.846} \overline{P}_A^{\,2.05}$ Hydrologic Regions 2, 3 & 4 Only	92.1	0.958859
$\overline{Q}_{MAY} = 1.86 \times 10^{-3} DA^{0.903} \overline{P}_A^{\,1.98}$	90.5	1.07231
$\overline{Q}_{JUN} = 10^{(-1.47+0.0729H)} DA^{0.891} C^{0.404} \overline{P}_{JUN}^{\,1.84} (1+F)^{0.326} G^{-0.387}$ Hydrologic Regions 2, 3 & 4 Only	97.0	0.193715
$\overline{Q}_{JUN} = 8.13 \times 10^{-3} DA^{0.828} C^{0.478} \overline{P}_{JUN}^{\,2.70}$	95.9	0.256941
$\overline{Q}_{JUL} = 1.78 \times 10^{-3} DA^{0.923} \overline{A}_{JUL}^{\,4.19}$	91.7	0.542940
$\overline{Q}_{AUG} = 4.17 \times 10^{7} DA^{0.981} (1+B')^{-1.64} (1+U)^{0.692} \overline{P}_A^{\,-7.2} \overline{A}_{AUG}^{\,4.59}$	90.4	1.11413
$\overline{Q}_{SEP} = 1.63 DA^{1.39} B^{-1.08}$	86.9	1.53072
$\overline{Q}_{OCT} = 5.98 DA^{1.14} B^{-0.755} S^{-0.688} (1+B')^{-0.481}$	95.7	0.375296
$\overline{Q}_{NOV} = 5.79 DA^{1.17} B^{-0.701} G^{-0.463} (1+U)^{0.267} (1+B')^{-0.397}$	95.1	0.492686
$\overline{Q}_{DEC} = 0.785 DA^{1.18} B^{-0.654} (1+U)^{0.331} (1+B')^{-0.490}$	92.4	0.590576
$Q_{YEAR} = 3.164 \times 10^{-4} DA^{0.942} P_{YEAR}^{\,2.39} A_{YEAR}^{\,1.02} S^{-0.206} \overline{P}_A^{\,1.27} C^{0.121} (1+U)^{0.0966}$	83.9	32.6357 (n=716)

General Application

In general, the regression equations developed using multiple watershed characteristics will be better predictors than those using drainage area as the sole explanatory variable. The single exception to this appears to be for the May Average Flow worksheet where the PRESS statistic values indicate that use of drainage area alone results in the least error in the prediction of future observations.

Although 2002 land cover grids for the state are now available with 19 different classifications, the older 2000 land cover grids with 9 different classifications were used in developing the regression equations. The 2000 land cover grids should be used in development of flow estimates using the equations.

The equations were developed from stream gauge data for watersheds with relatively minor open water surface percentages relative to other types of land cover (see Table A-1). For application to lake watersheds, particularly those with small watershed/lake area ratios, the basin slope and land cover percentages taken from HUC-12 basins may need to be adjusted so that the hydraulic budget components of surface inflow and direct precipitation on the lake itself can be treated separately. One method of accomplishing this is by subtraction of lake water surface acreage from the total land cover and slope (lakes will have 0% slope) acreages and recalculation of the % coverages. The watershed (drainage) area used in the equations should not include the area of the lake surface.

Application to Ottumwa Lagoon - Calculations

Table A-5. Ottumwa Lagoon Hydrology Calculations

Lake	Ottumwa Lagoon	
Type	Impoundment	
Inlet(s)	Kettle Creek, unnamed creek	
Outlet(s)	Des Moines River	
Volume	467	(acre-ft)
Lake Area	18	(acres)
Mean Depth	6.68	(ft)
Drainage Area	2230	(acres)
Mean Annual Precip	35	(inches)
Mean Annual Class A Pan Evap	48	(inches)
Mean Annual Lake Evap	35.5	(inches)
Est. Annual Average Inflow	1984	(acre-ft)
Direct Lake Precip	204	(acre-ft/yr)
Est. Annual Average Det. Time (inflow + precip)	0.21	(yr)
Est. Annual Average Det. Time (outflow)	0.24	(yr)

9. Appendix B - Sampling Data

Table B-1. Data collected in 1979 by Iowa State University (Bachmann, 1980)

Secchi Depth (m)	0.5
Chlorophyll-a (ug/L)	77.3
Total Phosphorus (ug/l as P)	440.9
Kjeldahl Nitrogen (mg/L)	0.7
Ammonia Nitrogen (mg/L)	0.1
Nitrate+Nitrite Nitrogen (mg/L)	0.1
Seston Dry Weight (mg/L)	18
Turbidity	8.6
Total Hardness (mg/L) as $CaCO_3$	256
Calcium Hardness (mg/L) as $CaCO_3$	172.9
Total Alkalinity (mg/L) as $CaCO_3$	193.4
Dissolved Oxygen (mg/L)	8.5
Specific Conductance (micro-ohms/cm at 25^{o} C)	563
Sulfate (mg/L)	76.2
Chloride (mg/L)	35.7
Sodium (mg/L)	25.5
Potassium (mg/L)	5

Table B-2. Data collected in 1990 by Iowa State University (Bachmann, 1994)

Secchi Depth (m)	0.4
Chlorophyll-a (ug/L)	110.6
Total Phosphorus (ug/l as P)	297
Total Nitrogen (mg/L)	2.7
Inorganic Suspended Solids (mg/L)	15.8
Total Suspended Solids (mg/L)	30.2

Table B-3. Data collected in 2000 by Iowa State University (Downing and Ramstack, 2001)

Parameter	6/29/2000	7/26/2000	8/15/2000
Lake Depth (m)	1.5	2.1	2
Thermocline Depth (m)	NIL	NIL	NIL
Secchi Disk Depth (m)	0.2	0.2	0.3
Temperature(^{o}C)	-	24.8	29.5
Dissolved Oxygen (mg/L)	-	6.1	16.7
Dissolved Oxygen Saturation (%)	-	73	219
Specific Conductivity (µS/cm)	-	462	414.2
Turbidity (NTU)	-	39.7	515.8
Chlorophyll a (µg/L)	8	14.3	7.4
Total Phosphorus as P (µg/L)	409	216	246
Total Nitrogen as N (mg/L)	1.75	1.33	1.79
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.27	0.12	0.11
TN:TP ratio	4	6	7
pH	6.8	7.3	8.3
Alkalinity as $CaCO_3$ (mg/L)	287	151	160
Inorganic Suspended Solids (mg/L)	27	37	3
Volatile Suspended Solids (mg/L)	7	7	3
Total Suspended Solids (mg/L)	34	44	6

Table B-4. Data collected in 2001 by Iowa State University (Downing and Ramstack, 2002)

Parameter	5/30/2001	6/27/2001	7/31/2001
Lake Depth (m)	2	2.7	2.1
Thermocline Depth (m)	NIL	NIL	NIL
Secchi Disk Depth (m)	0.4	0.4	0.4
Temperature(^oC)	18.2	27.2	30.8
Dissolved Oxygen (mg/L)	15.1	18	23
Dissolved Oxygen Saturation (%)	160	227	308
Specific Conductivity (µS/cm)	377	410.5	409.1
Turbidity (NTU)	72.9	56.1	81.2
Chlorophyll a (µg/L)	116.9	108.5	224
Total Phosphorus as P (µg/L)	393	213	309
Total Nitrogen as N (mg/L)	2.81	3	2.01
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.21	-	0.29
TN:TP ratio	7	14	6
pH	7	7.7	8.3
Alkalinity as $CaCO_3$ (mg/L)	118	131	116
Inorganic Suspended Solids (mg/L)	7	30	8
Volatile Suspended Solids (mg/L)	3	9	20
Total Suspended Solids (mg/L)	11	38	28

Table B-5. Data collected in 2002 by Iowa State University (Downing et al., 2003)

Parameter	6/5/2002	7/10/2002	8/7/2002
Lake Depth (m)	2.1	2.4	2.4
Thermocline Depth (m)	NIL	NIL	NIL
Secchi Disk Depth (m)	0.3	0.3	0.3
Temperature(^oC)	23.7	28.4	26.6
Dissolved Oxygen (mg/L)	-	6.5	6.3
Dissolved Oxygen Saturation (%)	-	83	79
Specific Conductivity (µS/cm)	603.4	436.1	558.8
Turbidity (NTU)	88.1	69.4	48.6
Chlorophyll a (µg/L)	84.5	164.8	32.4
Total Phosphorus as P (µg/L)	231	291	256
SRP as P (µg/L)	29	43	32
Total Nitrogen as N (mg/L)	2.23	1.58	1.51
Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	603	696	692
Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	16	23	37
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.92	0.19	0.13
TN:TP ratio	10	5	6
pH	7.7	7.7	7.9
Alkalinity as $CaCO_3$ (mg/L)	166	144	174
Silica as Si (mg/L)	6.72	6.75	8.19
Dissolved Organic Carbon (mg/L)	-	-	9.58
Inorganic Suspended Solids (mg/L)	29	8	32
Volatile Suspended Solids (mg/L)	15	7	13
Total Suspended Solids (mg/L)	44	15	45

Table B-6. Data collected in 2003 by Iowa State University (Downing et al., 2004)

Parameter	6/4/2003	7/9/2003	8/6/2003
Lake Depth (m)	2	2.4	2.5
Thermocline Depth (m)	1	NIL	NIL
Secchi Disk Depth (m)	2	0.3	0.3
Temperature(^{o}C)	19.8	28.2	26.7
Dissolved Oxygen (mg/L)	10	4.9	11.3
Dissolved Oxygen Saturation (%)	110	63	141
Specific Conductivity (µS/cm)	599.8	508.6	558.1
Turbidity (NTU)	60.8	48	64.7
Chlorophyll a (µg/L)	17.8	-	24.1
Total Phosphorus as P (µg/L)	353	495	304
SRP as P (µg/L)	32	181	16
Total Nitrogen as N (mg/L)	2.43	2.43	4.48
Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	492	1206	807
Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	22	69	53
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.11	0.17	2
TN:TP ratio	7	5	15
pH	8.1	7.9	8
Alkalinity as $CaCO_3$ (mg/L)	132	113	117
Silica as Si (mg/L)	7.96	9.09	6.32
Dissolved Organic Carbon (mg/L)	9.53	10.32	8.54
Inorganic Suspended Solids (mg/L)	21	20	22
Volatile Suspended Solids (mg/L)	19	15	19
Total Suspended Solids (mg/L)	40	35	41

Table B-7. Data collected in 2004 by Iowa State University (Downing et al., 2005)

Parameter	6/2/2004	6/30/2004	8/4/2004
Lake Depth (m)	1.4	2.3	2.4
Thermocline Depth (m)	NIL	NIL	0.6
Secchi Disk Depth (m)	0.2	0.3	0.2
Temperature(^{o}C)	20.1	23.7	27
Dissolved Oxygen (mg/L)	5.9	10.8	11.8
Dissolved Oxygen Saturation (%)	65	128	148
Specific Conductivity (µS/cm)	403	462.3	315.1
Turbidity (NTU)	149.1	158.3	100.1
Chlorophyll a (µg/L)	96.2	64	139
Total Phosphorus as P (µg/L)	205	248	355
SRP as P (µg/L)	60	21	21
Total Nitrogen as N (mg/L)	1.78	1.57	4.31
Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	1212	409	633
Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	38	19	77
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.23	0.11	0.23
TN:TP ratio	9	6	12
pH	7.9	8	8.3
Alkalinity as $CaCO_3$ (mg/L)	128	159	99
Silica as Si (mg/L)	10.76	5.11	8.06
Dissolved Organic Carbon (mg/L)	4.09	4.61	2.82
Inorganic Suspended Solids (mg/L)	85	51	39
Volatile Suspended Solids (mg/L)	23	19	24
Total Suspended Solids (mg/L)	107	70	63
Microcystin (µg/L)	1	2.5	12.6

Table B-8. 2000 - 2004 Phytoplankton Data (Downing et al., 2001 - 2005)

Division	2004	2003	2002	2001
Bacillariophyta Wet Mass (mg/L)	42.113	1.549	0.79	6.744
Chlorophyta Wet Mass (mg/L)	1.602	0.254	0.784	0.479
Chrysophyta Wet Mass (mg/L)	0	0	0.34	0
Cryptophyta Wet Mass (mg/L)	0.094	0.28	0.173	2.118
Cyanobacteria Wet Mass (mg/L)	10649.185	16.897	124.2	2.107
Dinophyta Wet Mass (mg/L)	0	0	0.177	0.352
Euglenophyta Wet Mass (mg/L)	0.693	1.364	2.362	0.097
Total	10693.688	20.343	128.826	11.897
TaxonomicRichness	9	12	13	6

Table B-9. IDNR/EPA RAFT Fish Tissue Chlordane Concentrations (mg/kg)

Species	1998	1999	2000	2001	2002
Common Carp	0.39	0.24	0.24	-	0.24
Channel Catfish	-	0.32	0.87	0.03	0.78
Largemouth Bass	0.1	-	-	0.03	-

Additional lake sampling results and information can be viewed at
http://limnology.eeob.iastate.edu/ and http://www.iowadnr.com/water/tmdlwqa/wqa/raft.html

10. Appendix C - Trophic State Index

Carlson's Trophic State Index

Carlson's Trophic State Index is a numeric indicator of the continuum of the biomass of suspended algae in lakes and thus reflects a lake's nutrient condition and water transparency. The level of plant biomass is estimated by calculating the TSI value for chlorophyll-a. TSI values for total phosphorus and Secchi depth serve as surrogate measures of the TSI value for chlorophyll.

The TSI equations for total phosphorus, chlorophyll and Secchi depth are:

$$\mathrm{TSI\ (TP)} = 14.42 \ln(\mathrm{TP}) + 4.15$$

$$\mathrm{TSI\ (CHL)} = 9.81 \ln(\mathrm{CHL}) + 30.6$$

$$\mathrm{TSI\ (SD)} = 60 - 14.41 \ln(\mathrm{SD})$$

TP = in-lake total phosphorus concentration, ug/L

CHL = in-lake chlorophyll-a concentration, ug/L

SD = lake Secchi depth, meters

The three index variables are related by linear regression models and *should* produce the same index value for a given combination of variable values. Therefore, any of the three variables can theoretically be used to classify a waterbody.

Table C-1. Changes in temperate lake attributes according to trophic state (modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987).

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	warm water fisheries only; percid fishery; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	Centrarchid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

Table C-2. Summary of ranges of TSI values and measurements for chlorophyll-a and Secchi depth used to define Section 305(b) use support categories for the 2004 reporting cycle.

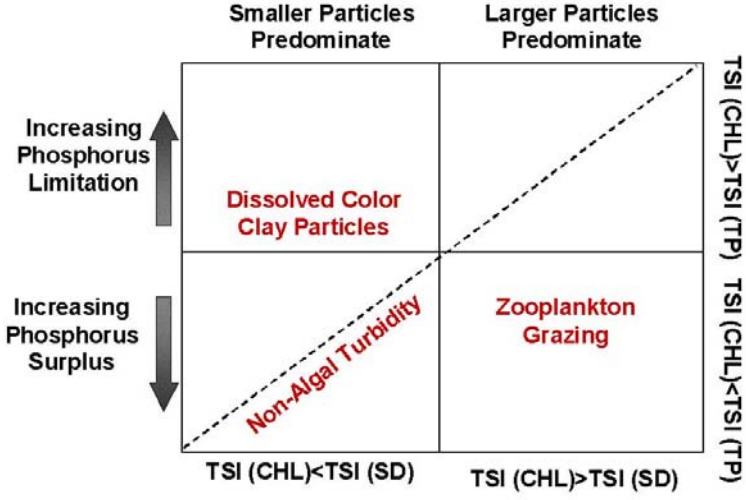
Level of Support	TSI value	Chlorophyll-a (ug/l)	Secchi Depth (m)
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 → 65	*12 → 33*	*1.4 → 0.7*
partially supported (evaluated: in need of further investigation)	65 → 70	*33 → 55*	*0.7 → 0.5*
partially supported (monitored: candidates for Section 303(d) listing)	65-70	*33 → 55*	*0.7→ 0. 5*
not supported (monitored or evaluated: candidates for Section 303(d) listing)	>70	*>55*	*<0.5*

Table C-3. Descriptions of TSI ranges for Secchi depth, phosphorus, and chlorophyll-a for Iowa lakes.

TSI value	Secchi description	Secchi depth (m)	Phosphorus & Chlorophyll-a description	Phosphorus levels (ug/l)	Chlorophyll-a levels (ug/l)
> 75	extremely poor	< 0.35	extremely high	> 136	> 92
70-75	very poor	0.5 – 0.35	very high	96 - 136	55 – 92
65-70	poor	0.71 – 0.5	high	68 – 96	33 – 55
60-65	moderately poor	1.0 – 0.71	moderately high	48 – 68	20 – 33
55-60	relatively good	1.41 – 1.0	relatively low	34 – 48	12 – 20
50-55	very good	2.0 – 1.41	low	24 – 34	7 – 12
< 50	exceptional	> 2.0	extremely low	< 24	< 7

The relationship between TSI variables can be used to identify potential causal relationships. For example, TSI values for chlorophyll that are consistently well below those for total phosphorus suggest that something other than phosphorus limits algal growth. The TSI values can be plotted to show potential relationships as shown in Figure C-1.

Figure C-1. Multivariate TSI Comparison Chart (Carlson)



Ottumwa Lagoon TSI Values

Table C-4. 1979 Ottumwa Lagoon TSI Values (Bachmann)

TSI (SD)	TSI (CHL)	TSI (TP)
70	73	92

Table C-5. 1990 Ottumwa Lagoon TSI Values (Bachmann)

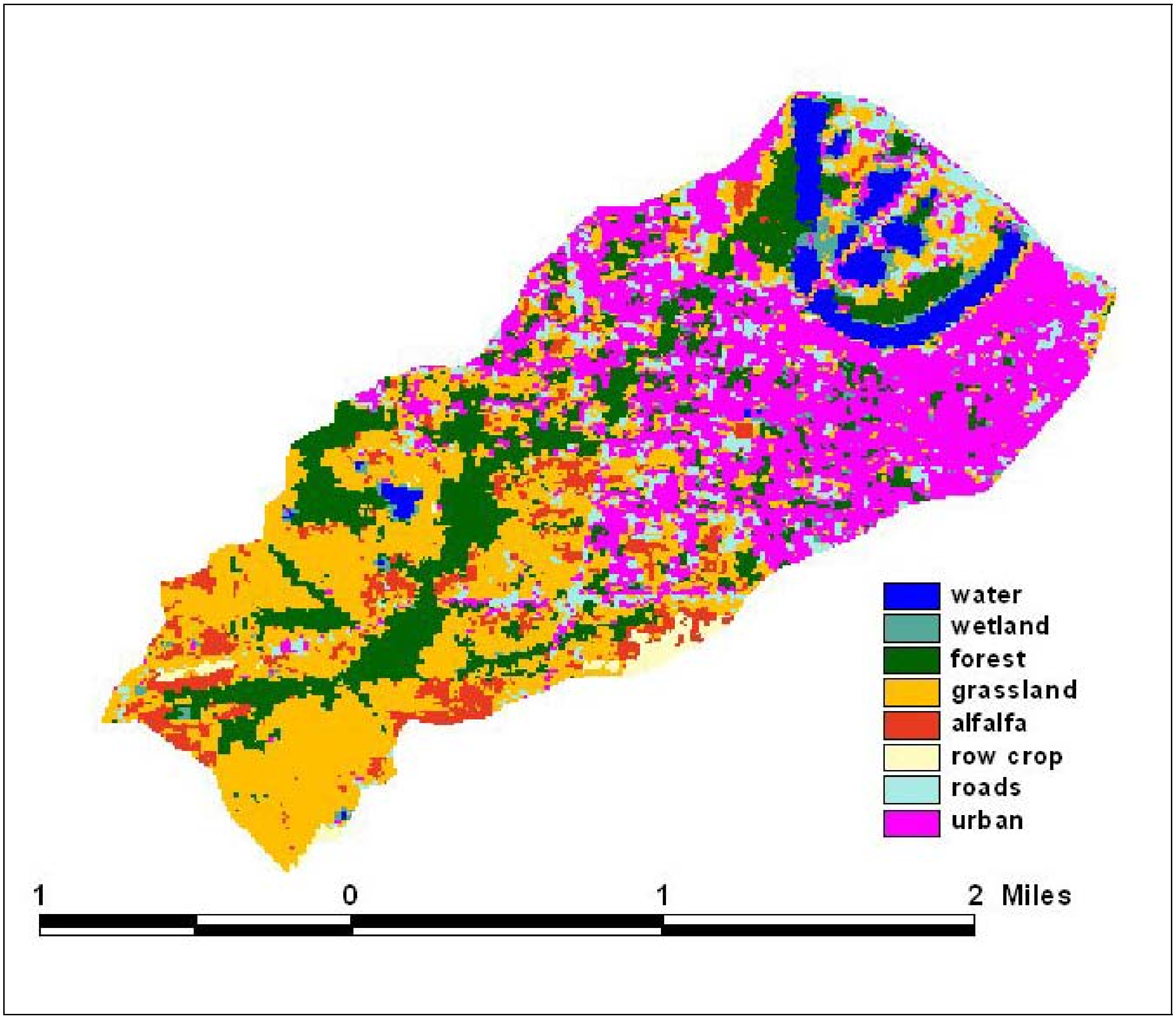
TSI (SD)	TSI (CHL)	TSI (TP)
73	77	86

Table C-6. 2000 - 2004 Ottumwa Lagoon TSI Values (Downing et al.)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/29/2000	83	51	91
7/26/2000	83	56	81
8/16/2000	77	50	81
5/30/2001	73	77	90
6/27/2001	73	77	81
7/31/2001	73	84	86
6/5/2002	77	74	83
7/10/2002	77	81	86
8/7/2002	77	65	84
6/4/2003	50	59	89
7/9/2003	77	0	94
8/6/2003	77	62	87
6/2/2004	83	75	81
6/30/2004	77	71	84
8/4/2004	83	79	89

11. Appendix D - Land Use Map

Figure D-1. Ottumwa Lagoon Watershed 2002 Landuse



12. Appendix E - Ottumwa Lagoon Phosphorus Loading

Figure E-1. Ottumwa Lagoon Target Internal vs. External Load